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Dependence between Oil Price and Exchange Rate Volatility: An Empirical Analysis

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Abstract
We study the oil price and the USD/INR exchange rate volatility co-movement using a modified multivariate Dynamic Conditional Correlation (DCC) – GARCH model. The model jointly estimates the dynamic conditional correlation of USD/INR rate with volatility in oil price in the presence of the USD/EURO rate providing control for any exogenous variability. The findings reveal that oil and USD/INR volatility co-movement is weak. However, the unusual global events like the financial crisis of 2008 and oil prices crash of 2014 lead to strong co-movement. We provide empirical evidence for USD/INR as a better choice for the Central Bank of India (RBI) to monitor for the policy design that deals with inflationary effects of oil price, interest rate change, and overall economic stability. The findings have implications not only for policymakers involved in controlling negative impacts on the real economy due to exchanged rates fluctuations or inflationary effects of oil price but also for risk management practitioners involved in managing effects of adverse oil shocks and exchange rate movements.

Keywords: Oil, Exchange rate, Volatility, Co-movement, DCC-GARCH

JEL: C32, G15, F31

1. Introduction

Oil is an essential nonrenewable natural commodity with astounding implications on all economies of the world. India meets its energy requirement primarily from oil imports, and thus oil price has enormous ramifications on its economy. In the context of emerging nations like India, the economic slowdown, trade deficit, higher inflation, and consequently uncertain investment ambiance have often been attributed to sudden and large fluctuations in oil prices.

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The volatility of oil price increased after the international oil crises of 1973 and 1979, followed by an oil price collapse during the 1980s. Oil price increased continually and reached a peak price at above $145 a barrel in 2008. This increase in oil price could be due to political unrest in the Middle East, which has more than 66% of OPEC's oil reserve. Then oil price decreased steeply from about $145 a barrel in July 2008 to approximate $38 a barrel in March 2016. The reasons behind the downturn in oil prices is often attributed to the following factors a) US domestic crude oil production has doubled for past few years and consequently oil which was sold in the US, was now competing in Asian market, b) return of Iran in international oil marketplace, after UN sanctions were lifted, and c) oil being major cash cow in Russia's troubled economy- which has created supply glut.

India's oil bill was above $100 billion in 2014-2015, which was close to 10% of its GDP. Guivarch et al. (2009) documented the implication of oil price shocks on policymaking while Gupta (2008) estimated oil vulnerability index of oil-importing countries. India ranked third (1st being the most vulnerable) only after the Philippines and Korea. Therefore oil price shocks play a crucial role in policy making in emerging countries like India. Plorude and Watkins (1998) and Regnier (2007) empirically found that oil price volatility tends to be more unpredictable than the price of other energy products post-mid-1980s. Efficiency in the oil market and its pricing is critical, as profitable trading opportunities might exist if the futures market of crude oil is not efficient (Shambora and Rossiter, 2007).

The volatility of the US dollar (USD) exchange rate is an important factor in oil price volatility, as USD is the preferred transaction currency in oil markets and thus has repercussion for oil importing and exporting economies. A strengthened USD may unfavorably affect oil-importing nations like India, which in the long term could lead to a demand shock that eventually disturbs oil-exporting countries. On the other hand, a weak USD gives greater purchasing power to the oil-importing nations (except the US) and affects the oil exporting nations negatively. Therefore, oil traders continually monitor the oil price the USD rates, because the co-movement between volatility in oil price and USD exchange rate could present investment and speculation opportunity for them. Hence, the study of co-movement of the currency markets and oil is of great interest not only for investors and but also for policymakers in an emerging economy like India as it may change the interest rates through Central Bank intervention.

Here we focus on the co-movement between volatility in oil price and critical foreign exchange rates and its impact on the emerging economy like India. The Reserve Bank of India (RBI), when concerned about inflation stability, would be less likely to favor interest rates hike if a positive co-movement occurs in oil price and USD rate, owing to the fact that the inflationary consequences of volatility in oil price are balanced to a certain degree by USD depreciation. On the other hand, when the exchange rate and oil prices do not reveal significant co-movement, then an increase in oil price is expected to prompt the regulator to change the interest rates. Moreover, RBI might also desire to achieve either depreciation or an appreciation level for Indian Rupee (INR) against USD. Such policy design could also get influenced by the co-movement of oil prices and foreign exchange rates. Economic shocks in oil price are more inclined to move interest rates if there is a significant co-movement between exchange rate and oil price, irrespective of whether the economy belongs to a net exporter or net importer of oil.

The earlier empirical research engaged a variety of econometric methodologies, such as the cointegration model and the vector autoregressive model and error correction model to study the

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dynamics of oil price and exchange rate on economic and currency policies. However, not much is known about oil price-exchange rate volatility co-movements and its implication on the central bank's policymaking, particularly in the context of an emerging country like India. The study tries to plug this research gap by studying the co-movement between -USD/INR exchange rate and oil price and compare it with the co-movement of the USD/EURO rate and oil using DCC-GARCH.

The remaining part of this research paper is organized as follows. Section 2 presents a review of the previous research that looks into the relationship between the currency and the oil markets. In Section 3, we discuss the data and methodology. Section 4 describes dynamic conditional correlation estimations from DCC-GARCH employed for this research and Section 5 concludes the study and highlights the scope of future research.

2. Literature Review

General finding in existing empirical literature reveals that there is a negative relationship between oil price and the USD rate. Golub (1983) and Krugman (1983) concluded that for the oil importing nation, there might be an exchange rate depreciation with a rise in oil prices, and appreciation with a fall in oil prices. Their finding was precisely the opposite for oil-exporting nations. Moreover, Bloomberg and Harris (1995) studied the bearing of exchange rates on oil price volatility where they argued, as oil is an globally traded commodity priced in domestic currency of the USA, i.e., USD, any depreciation in USD decreases the oil import bill to exchequer of oil-importing nations except the USA, comparative to the price of their own commodities, hence increasing their purchasing power which in turn increases the oil demand and therefore oil price in USD increases. Amano et al. (1998) employed co-integration and ECM to conclude that oil prices do influence the US exchange rate but not vice versa. Chen et al. (2007) added that the USD exchange rate is robust to different measures of oil prices. Akram (2009), Reboredo (2011) and Wu et al. (2012) re-confirmed the negative dependence structure of USD exchange rate and oil price with a decreasing trend. However, Narayan et al. (2008) used models from the GARCH family on daily data, from 2000 to 2006, to show that increased oil price culminated to an appreciation of the USD. Riadh et al. (2013) modeled daily data between 2000-2011 using Copula and GARCH to conclude that appreciation of USD concurs with an increase in oil price. Pershin et al. (2016) provides a good summary of the related work done on the oil price and exchange rate nexus and conclude that no general rule can be made for net oil importing sub-Saharan countries.

In summary, oil price and USD has shown a dependence structure, which may not be similar for oil-importing nations and oil-exporting nations. Lizardo et al. (2010) document that USD depreciated against the currencies of oil-exporting nations and it depreciated against the currencies of oil-importing nations when oil price increased.

3. Data and Methodology

The study investigates co-movement of oil price volatility vis-a-vis two exchange rates (USD/INR and USD/EURO) for a 16-year period from April 2000 to March 2016 collected from economic research data of Federal Reserve System. The time period covers the 2008 financial crisis and its aftershocks. The volatility comovement between exchange rates and the oil price were explored using the multivariate DCC-GARCH model on log returns of each data series.

Daily return y_t from respective series is computed given below.

$$y_t = (lnP_t - lnP_{t-1}) * 100 \quad (1)$$

3.1 Univariate GARCH with Asymmetric (GJR) extension

In volatility modeling, one of the most influential change came with Engle(1982)'s ARCH. Bollerslev (1986) extended it further to Generalized ARCH or GARCH model.

The simplest GARCH (p,q) for time-varying condition variance can be summarized as

$$\sigma_t^2 = \omega + \sum_{i=0}^{p} \alpha_i \varepsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_i \sigma_{t-1}^2 \quad (2)$$

$$\varepsilon_t = \sigma_t Z_t \quad (2.a)$$

Z_t~N(0,1) and ε_t~ i.i.d

Moreover, all the parameters ω, α_i 's and β_i 's are positive, in order to σ_t^2 to remain positive.α_i can be seen as information absorbtion co-efficient and β_i as persistence co-efficient.

Glosten, Jaganathan, and Runkel (1993) model take into account the leverage effects in which a dummy variable γ is introduced. With the aforementioned GJR extension equation (2) changes to:

$$\sigma_t^2 = \omega + \sum_{i=0}^{p} \alpha_i \varepsilon_{t-1}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \sum_{j=1}^{q} \beta_i \sigma_{t-1}^2 \quad (3)$$

where d_t = 1 if ε_t< 0, and 0 otherwise. Now this model ε_t< 0 (Bad news) will have different effect on conditional variance than ε_t> 0 (Good news). Bad news has an additional impact of γ that signifies the leverage effect. If γ is positive and statistically significant, then it can be said that there is a leverage effect as bad news impacts more severely.

3.2 The Multivariate DCC-GARCH Model

The assumption our model makes is that three-time series (Oil, USD/INR, and USD/EURO) are multivariate normally distributed series and their conditional variance-covariance matrix is represented by H_t. The DDC-GARCH model can be represented as shown below:

$$r_t = \mu_t + \varepsilon_t \quad (4)$$

With $\varepsilon_{t/\Omega_{t-1}}$ → N (0, H_t) where r_t is the 3x 1 vector of the returns, ε_t, a 3 x 1 vector, is return innovations conditioned on information. Conditional variance-covariance matrix H_t in the DCC-GARCH model can be expressed as

$$H_t = D_t R_t D_t \quad (5)$$

Where D_t represents a K x K (3 x 3) diagonal matrix of conditional volatility of returns of each series and R_t is K x K (3 x 3) conditional correlation matrix. The DCC-GARCH model offer only

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$R_t$to be time varying. R_t remains the correlation matrix. Based on this matrix of DCC, the co-movement of the volatility of each series can be estimated. Our model jointly estimates the dynamic conditional correlation of USD/INR rate with volatility in oil price in the presence of the USD/EURO rate. This provides control for any exogenous variability in the USD exchange rate, making our model robust and more reliable.

4. Results and Discussion

Table 1 summarizes the key descriptive statistics of the three-time series. It can be observed that the return from oil has maximum variability compared to the two exchange rates that have been used in the study. It can also be observed that Kurtosis is maximum in case of the USD/INR exchange rate, indicating a fat tail.

Table 1: Descriptive Statistics

DETAILS	*OIL*	*EURO*	*INR*
Mean	0.01	0	-0.01
SD	2.52	0.64	0.47
Median	0.08	0	0
Min	-17.09	-3	-3.94
Max	16.41	4.62	3.76
Skewness	-0.18	0.11	-0.17
Kurtosis	4.34	2.08	10.34
J-B Test	3202.7***	736.73***	18060***
Ljung-Box Q(12)	34.594***	15.017	51.144***
Ljung-Box Q^2(12)	1336.4***	479.57***	1108.2***
ARCH LM(12)	497.41***	266.19***	480.45***

Note: *** Significance at the 1% level.

Figure 1 shows the return and volatility of oil, USD/INR and USD/EURO rates. While returns plot appears to evolve in similar trend for all three series, the volatility plot (estimated by univariate GJR-GARCH) indicates that volatility measures of oil and USD/EURO co-moves, where the correlation is positive and significant. In the case of INR/USD, leaving financial crises period, volatility does not seem to be affected by that of oil. An approach is made to establish the conclusion through DCC-GARCH model.

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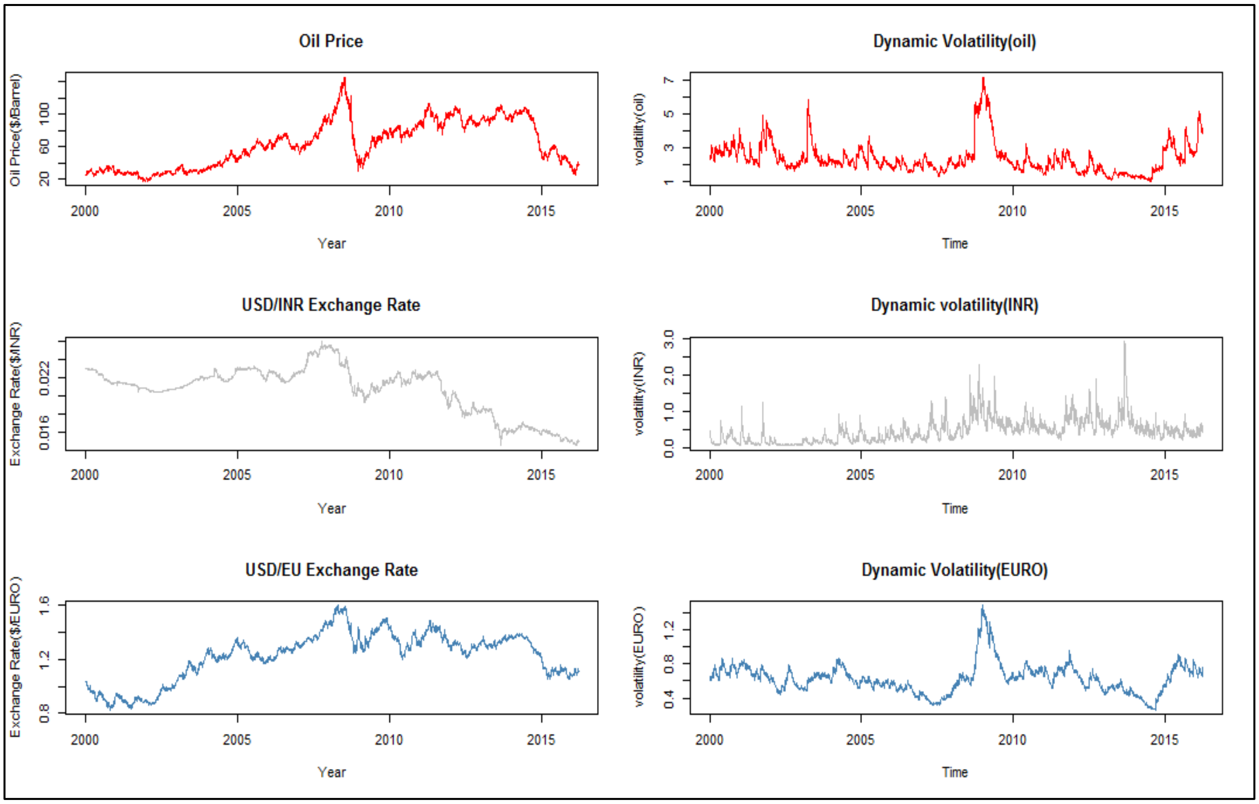

Figure 1: Return-Volatility Plot

Table 2 summarizes univariate asymmetric GARCH fit for oil return series. There is evidence of a strong leverage effect, i.e., adverse shocks or negative news is observed to have a higher degree of influence on the returns than that of positive news or shocks.

Oil return shows information absorption coefficient changes from 2.71% (α_1) to 6.48% ($\alpha_1 + \gamma_1$) on account of the leverage effect. Negative shocks like demand side shocks, politically instability in oil-exporting nations etc. affects oil price more than positive news like a surge in demand, currency appreciation of oil-importing nation.

Table 2: GJR-GARCH (1, 1) –OIL

Parameter	Estimate	Std. Error	t-value	Pr(>|t|)
Ω	0.025244	0.009758	2.5871	0.009679
α_1	0.027189	0.006457	4.211	2.50E-05
β_1	0.950041	0.004913	193.3774	0
γ_1	0.03768	0.010979	3.4319	0.000599

Figure 2 shows the GJR-GARCH fit for the oil series. The normality of the residuals and strong leverage is visible. The volatility of oil returns series is very high compared to USD/INR returns and USD/EURO returns.

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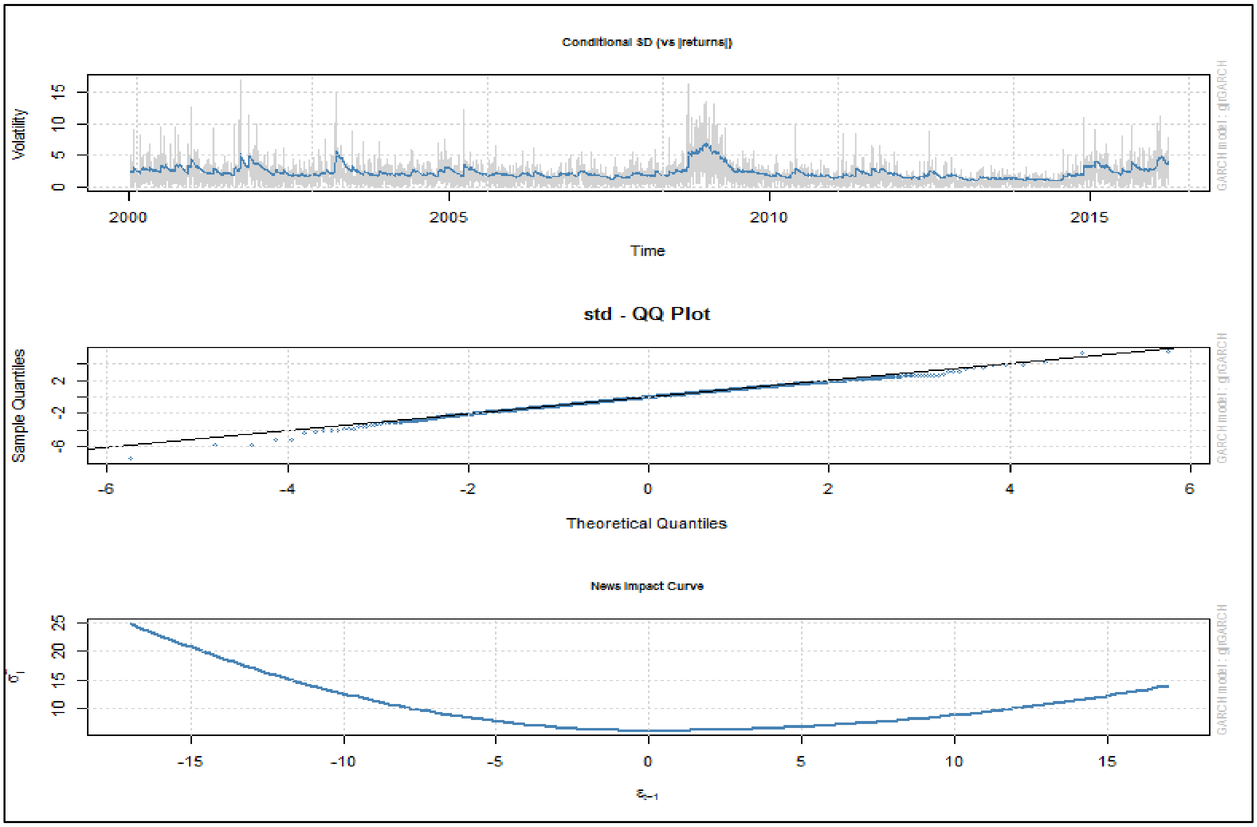

Figure 2: GJR-GARCH (1, 1)-OIL

Table 3 elaborates the asymmetric GARCH model for USD/INR returns where the presence of highest information absorption coefficient is verified, and leverage effect is not that strong in the case of USD/INR return as that of oil returns. It can also be noted that USD/INR returns have the lowest persistence coefficient (β_1). A high information absorption coefficient, moderate leverage effect and low persistence parameter indicates an efficient India forex market.

Table 3: GJR-GARCH (1, 1) – INR

Parameter	*Estimate*	*Std. Error*	*t-value*	*Pr(>|t|)*
Ω	0.000389	0.000155	2.5098	0.012079
α_1	0.113218	0.019001	5.9586	0
β_1	0.865171	0.021414	40.4027	0
γ_1	0.041223	0.017603	2.3418	0.019193

Figure 3 describes the lowest volatility in USD/INR returns in comparison to oil returns and USD/EURO returns. It is observed that volatility increased substantially during sub-prime crises, only to retract subsequently to its original course of low volatility.

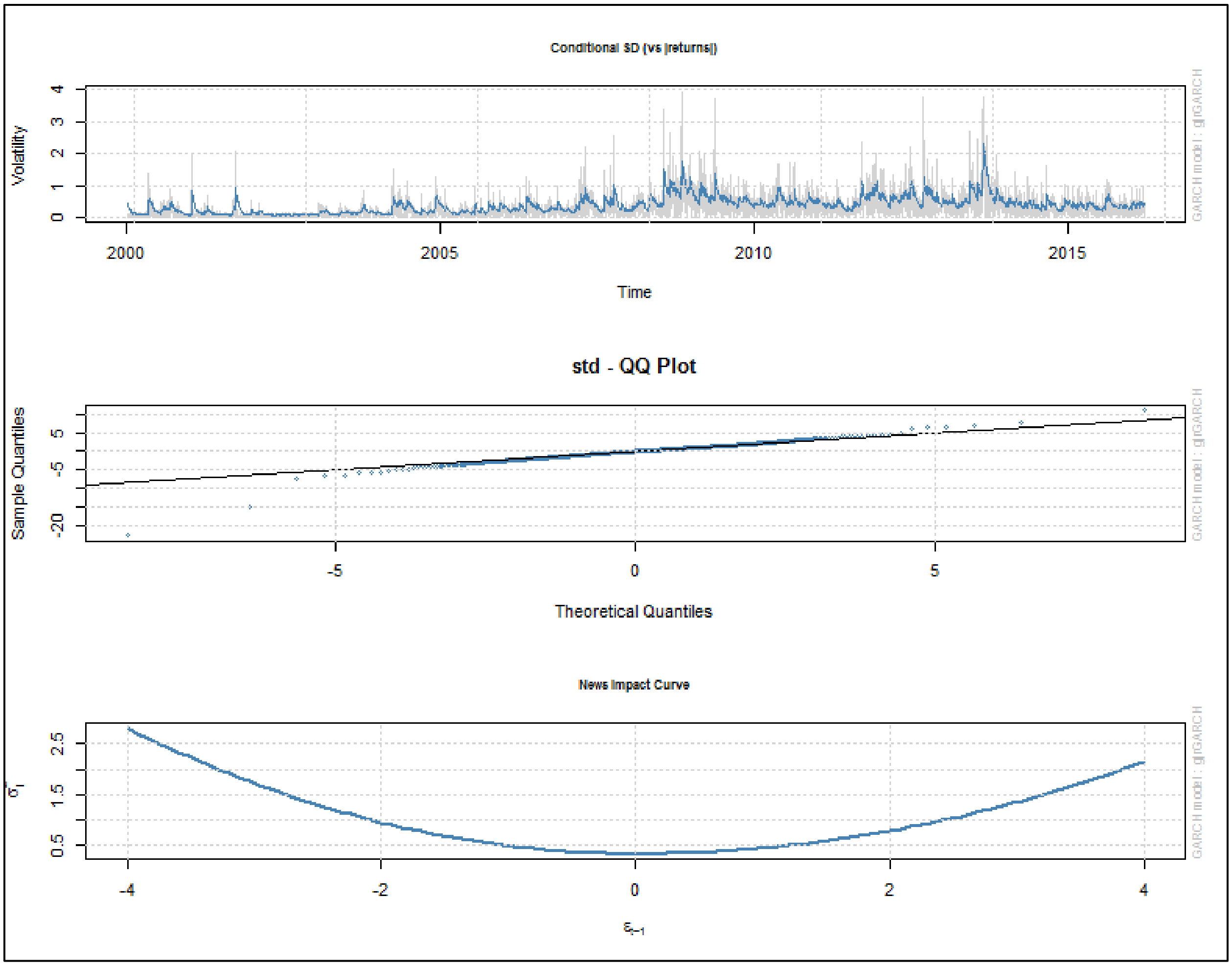

Figure 3: GJR-GARCH (1, 1) INR

Table 4 summarizes GJR-GARCH results from USD/EURO returns. In the case of the USD/EURO lowest information observation coefficient, the lowest leverage effect and the highest persistence coefficient are observed. USD/EURO market does not seem to confer efficient market hypothesis.

Table 4: GJR-GARCH (1, 1) – EURO

Parameter	*Estimate*	*Std. Error*	*t-value*	*Pr(>|t|)*
Ω	6.89E-04	4E-04	1.60135	0.1093
α_1	0.02495	0.004	6.7402	0
β_1	0.96802	3E-04	3296.88	0
γ_1	0.01207	0.006	1.85846	0.0631

Figure 4 describes the fitment of the univariate GARCH model for USD/EURO returns. It shows higher volatility than USD/INR and its pattern matches with that of oil returns. A further investigation of this match (co-movement) is made through the multivariate estimates.

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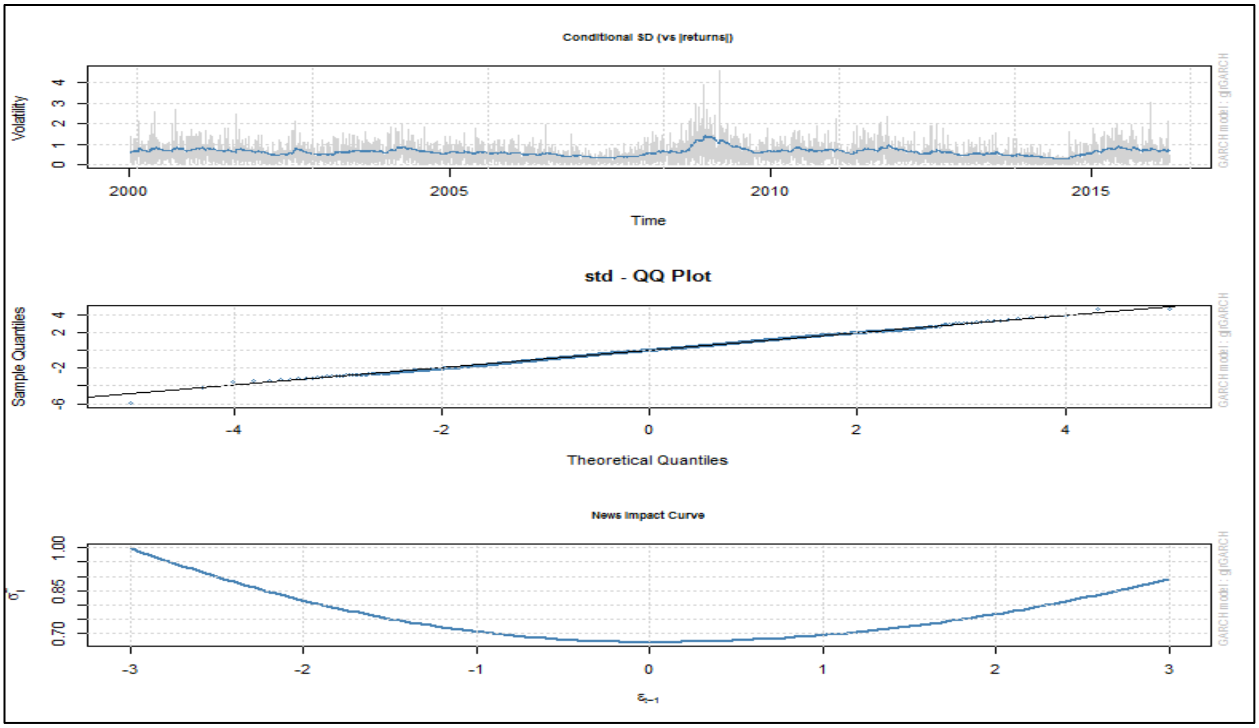

Figure 4: GARCH (1, 1)-EURO

Table 5 summarizes the DCC-GARCH estimates. It is observed that conditional correlation parameters (with covariance targeting) θ_1 and DCC parameter θ_2 are both statistically significant. It is also noted that 1- $(\alpha_1+\beta_1)$ is very close to θ_1 (0.88%) for all three return series, which indicates a good DCC-GARCH model.

Table 5: DCC-GARCH Results

Parameter	*Estimate*	*Std. Error*	*t-value*	*Pr(>|t|)*
[Oil].ω	0.036603	0.023432	1.56E+00	0.118261
[Oil].α_1	0.057683	0.017575	3.28E+00	0.001031
[Oil].β_1	0.938431	0.019611	4.79E+01	0
[INR]. ω	0.00126	0.000932	1.35E+00	0.176586
[INR]. α_1	0.11228	0.018867	5.95E+00	0
[INR]. β_1	0.88672	0.022979	3.86E+01	0
[EU]. ω	0.00115	0.000699	1.64E+00	0.099986
[EU]. α_1	0.029828	0.002139	1.39E+01	0
[EU]. β_1	0.967719	0.000468	2.07E+03	0
[Joint]θ_1	0.008886	0.002469	3.60E+00	0.000318
[Joint]θ_2	0.988164	0.003826	2.58E+02	0

Figure 5 shows the conditional correlation (co-movement) between USD/INR returns and oil returns. It is observed that before the financial crisis, co-movement is very small (correlation is less than 10%) but during the crises and its recovery period, highest co-movement (correlation is up to 40%) can be observed. Co-movement decreases from mid-2012 to mid-2014; however it gains momentum after the oil price crash, which started in mid-2014. India’s strong reliance on oil

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for its energy needs could be one of the plausible reasons for this increased co-movement during unusual global events like the financial crisis of 2008 or oil price crash 2014.

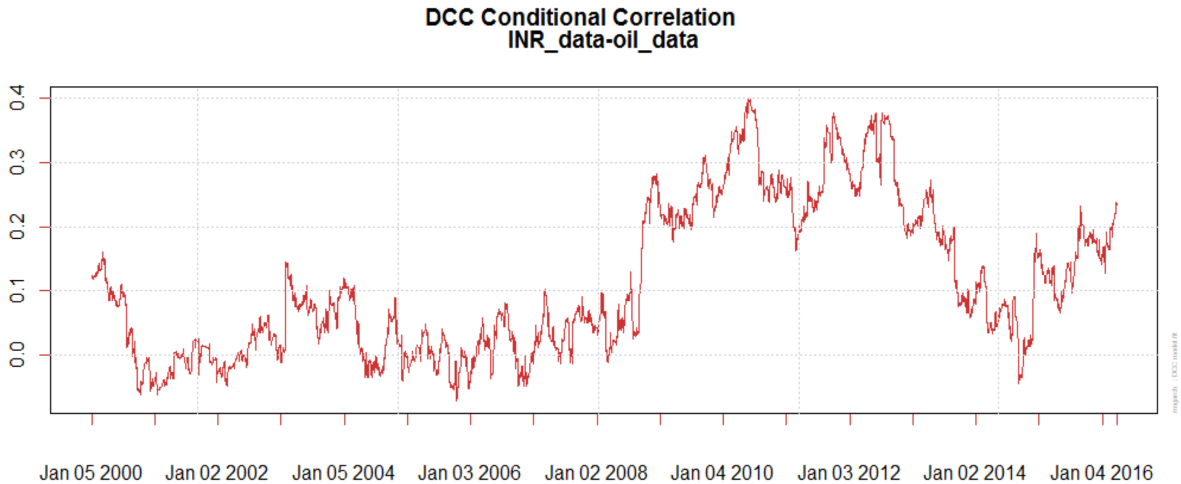

Figure 5: Conditional Correlation (USD/INR-OIL Return)

In Figure 6, the conditional correlation plot for oil returns and USD/EURO returns shows overall higher co-movement than that of USD/INR and oil. At the time of the financial crisis, it shows maximum co-movement (conditional correlation reaches up to 50%), and this higher co-movement prevails in the recovery period also. However, recent (May 2014) oil price crash does not seem to trigger very high co-movement between USD/EURO rate and oil price and.

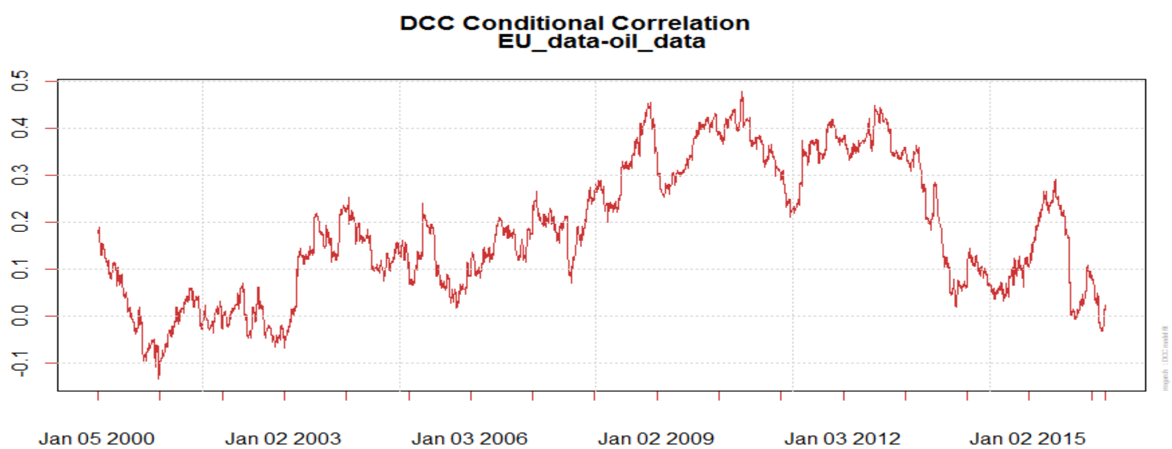

Figure 6: Conditional Correlation (EU/INR-OIL Return)

5. Conclusion

The crude oil price has a very pivotal role to play in any economy in general. India imports approximately 70% of its crude oil requirement with a significant burden on its exchequer (currently at approximately $62 billion). Jain (2013) found the significance of oil price on macroeconomic variables such as the wholesale price index, and stock market movement, etc. Srithar et al. (2015) documented that the crude oil price plays an important factor in the GDP growth rate of India.

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The co-movement between exchange rates (USD/INR and USD/EURO) and oil price volatility have been studied with substantial financial and economic ramification in the Indian context- from April 2000 until March 2016. The study was based on asymmetric univariate GARCH model and multivariate DCC model. The objective was to estimate the co-movement between volatility in oil price and exchange rate from the viewpoint of the Indian economy and consequently to assess whether or not oil shocks are partially offset by USD depreciation. USD/EURO exchange rate series was used as a reference for better understanding of structural dependence or co-movement of volatility in oil price and USD/INR rate. Before and during the financial crisis USD/EURO rate shows higher co-movement with oil price when compared to USD/INR rate, but USD/INR is consistent in co-movement when oil price started crashing in 2014. Therefore, it is a better choice for the RBI to monitor for the policy design that deals with the inflationary effects of oil price, interest rate change, and overall economic stability.

For normal circumstances (the period before the financial crisis or most of the recovery period), our empirical study could not find evidence for significant co-movement of volatility in oil price and USD/INR rate. However, during the crises evidence of higher co-movement was found (positive correlation), i.e., depreciation in USD and consequently the opportunity for offset effect. The results are in line with Turhan et al. (2012) argument that the relationship between exchange rates and oil prices are more relevant post global events like the 2008 economic crises. Our findings support the observations of Reboredo (2012) that in post-financial crises world, co-movement in oil price and USD-exchange rate rises significantly. Our findings have implications for policymakers as well as risk management practitioners involved in risk management practices in financial markets faced with oil shocks. For a foreign oil dependent country like India, the results may aid decision making by the Central Bank to control for inflationary effects of oil price or purchasing power setbacks due to strengthened exchanged rates, mainly USD/INR.

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